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Author(s): Wang, Zhehui

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# Studying dynamo and MRI in dusty plasmas

*Through machine learning of long-range correlated dust transport*

Zhehui (Jeph) Wang

[email: zwang@lanl.gov](mailto:zwang@lanl.gov)

*Los Alamos National Laboratory  
(1<sup>st</sup> COMPACT Science Definition Workshop  
Jan 15, 2021, B15-01-04, 9:15 am MT)*



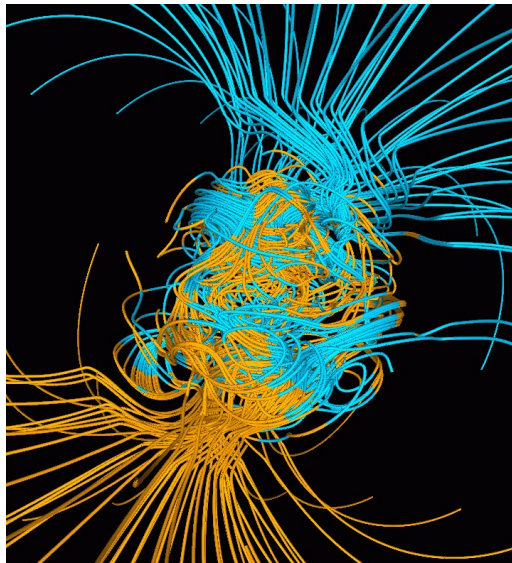
LANL Report #: LA-UR-21-20342

# OUTLINE

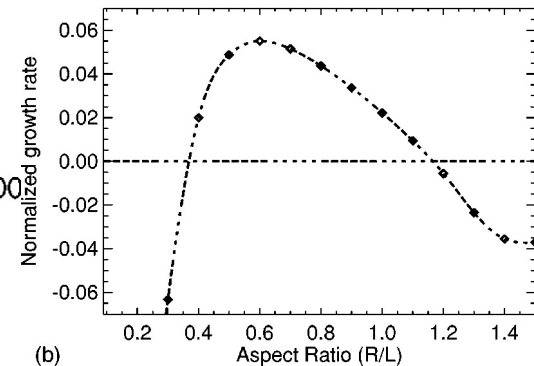
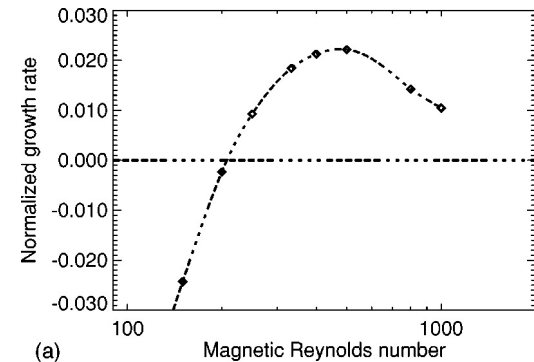
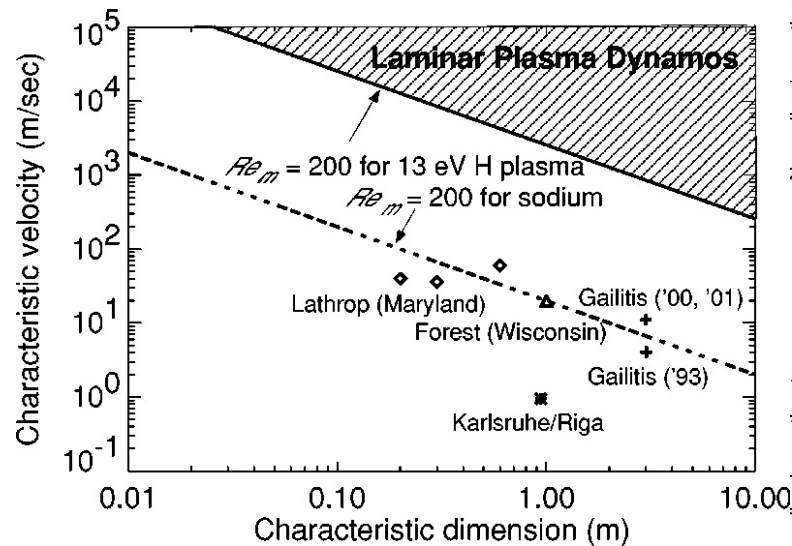
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- Laboratory studies of dynamo & Magneto-Rotational Instability (MRI) mechanisms
- Dusty plasmas as a platform for laboratory astrophysics
- Machine Learning (ML) of dust trajectories and transport
- A possible initial experiment

# Laminar Plasma Dynamos



Wiki: dynamo theory



Z. Wang, et al, Phys. Plasma. **9** (2002) 1491.

# Magneto-rotational instability (MRI) in astrophysics



Hubble & Webb images

**Mystery:** The ‘standard hydrodynamic & MHD models’ are **insufficient** to explain the observed emissions (accretion rate, and luminosity)

**Theoretical breakthroughs** motivate MRI:  
E. P. Velikhov (1959);  
S. Chandrasekhar (1960);  
S. A. Balbus & J. F. Hawley (1991, 1998);

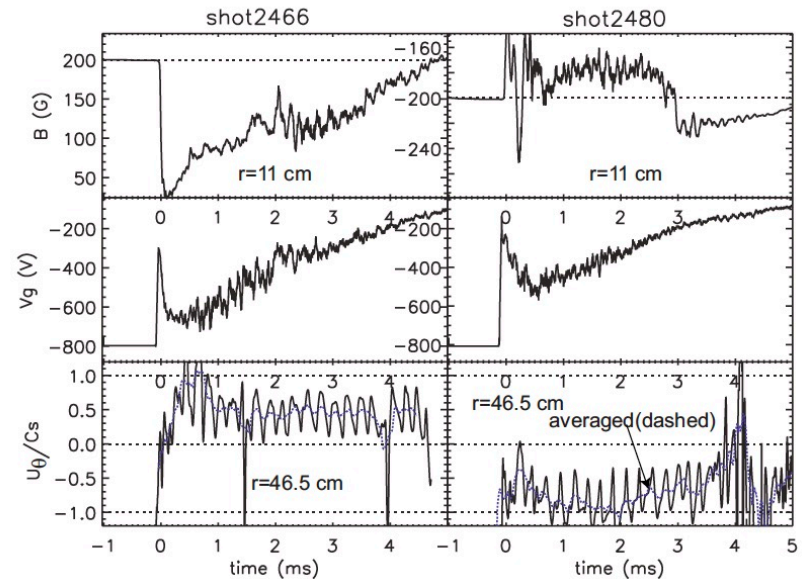
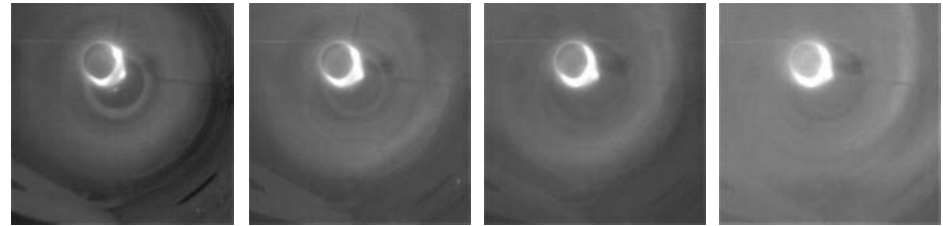
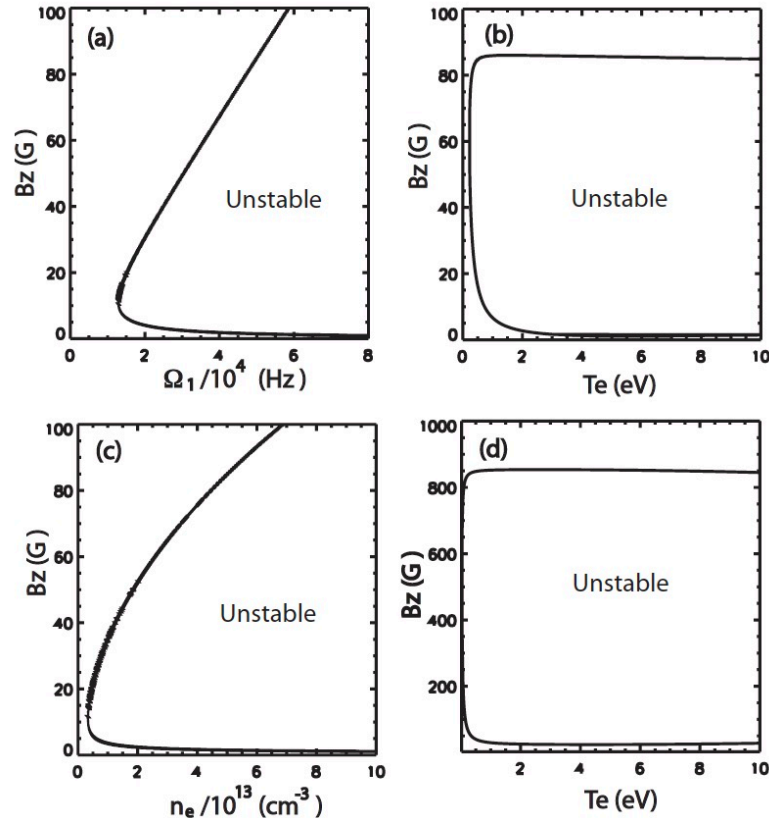
**Opportunities:** Laboratory validation of the physics mechanisms:

- > Princeton/PPPL, Liquid Metal
- > LANL, Plasma
- > Wisconsin, plasma

...

>> **Dusty plasma approach (this talk)**

# MRI in plasma Couette flows (LANL/FMP experiment)



Z. Wang, et al, Phys. Plasma. **15** (2008) 120109.

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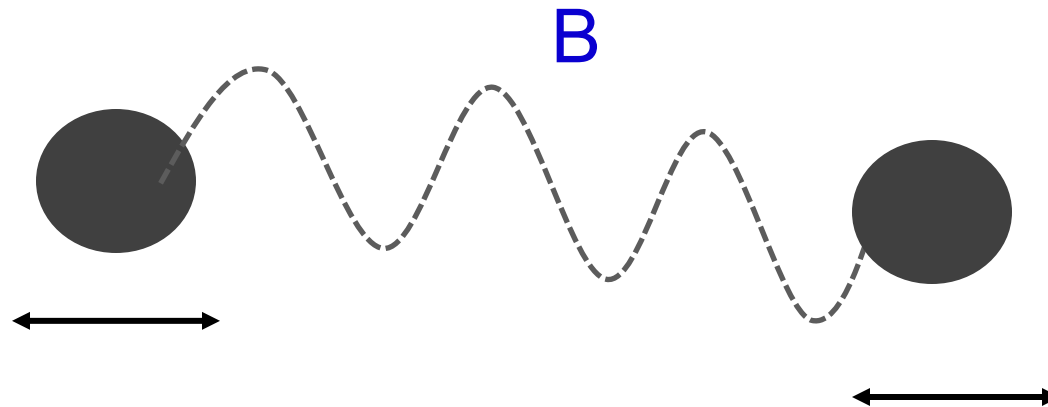
**“It is so very easy to make mistakes in magneto-hydrodynamics that one should not believe in a result obtained after a long and complicated mathematical derivation if one cannot understand its physical origin; in the same way, one cannot also believe in a long and complicated piece of physical reasoning if one cannot demonstrate it mathematically.”**

*--- From E. Fermi, Collected Papers, Vol II,  
Univ. Chicago Press (1965), p. 925*

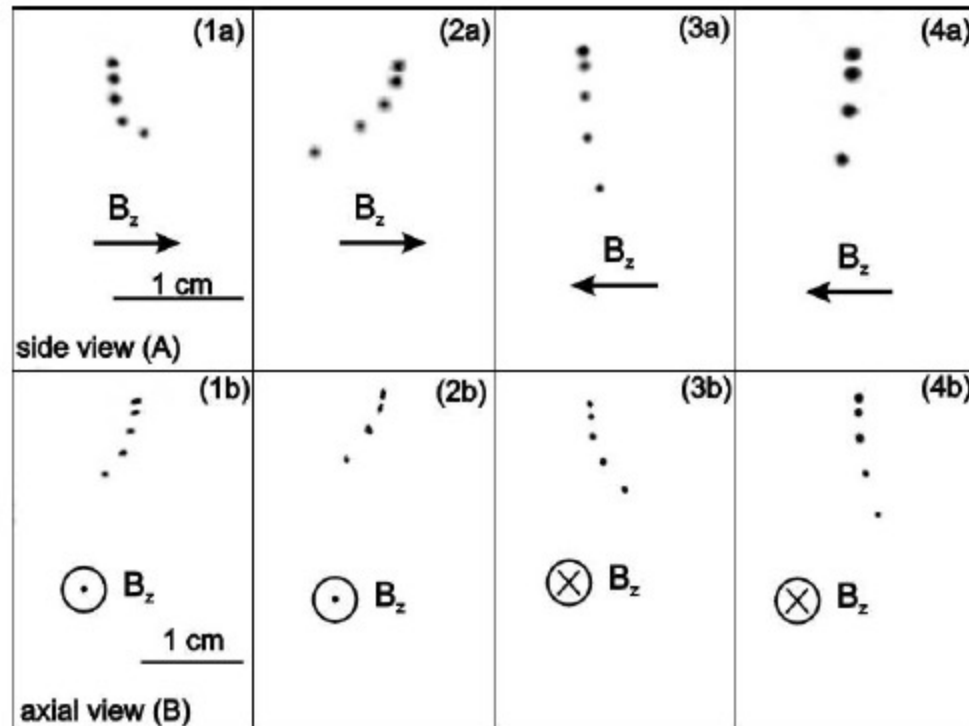
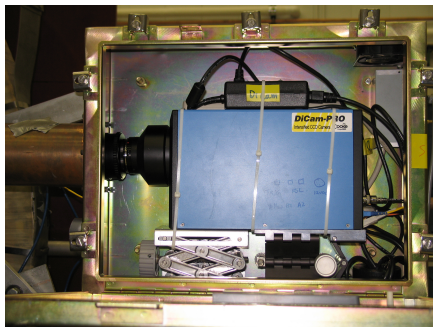
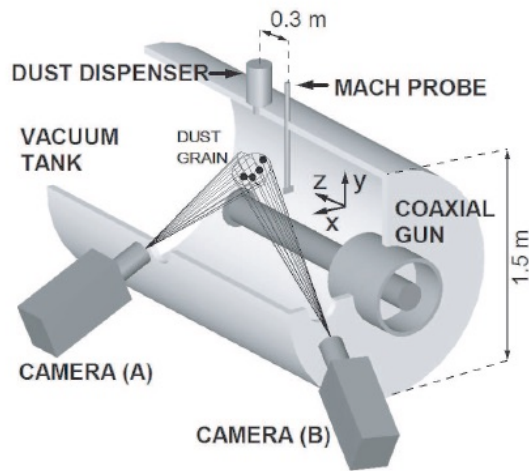


# An overly simplified view of MRI

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# Dusty plasmas as a laboratory astrophysics platform

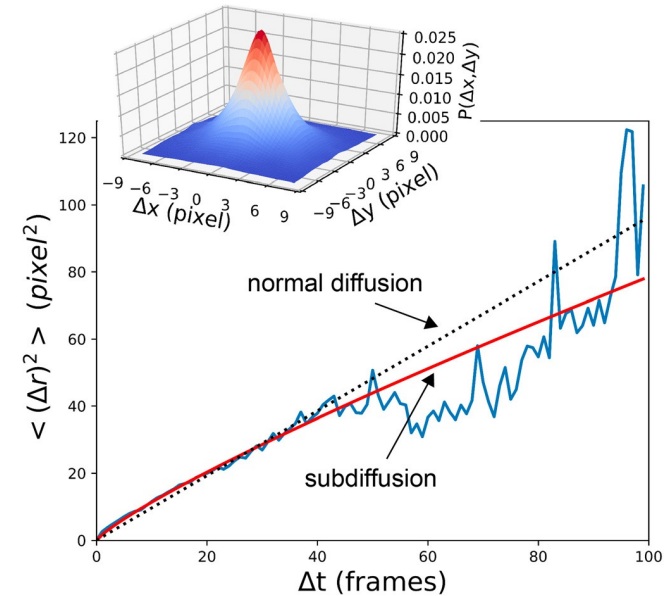
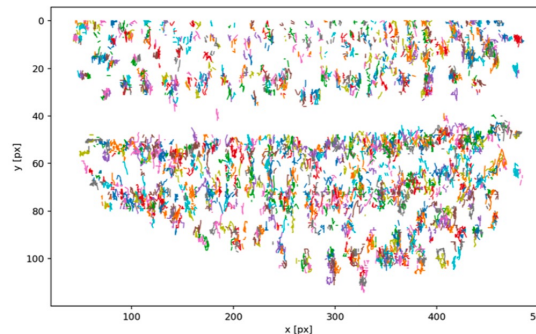
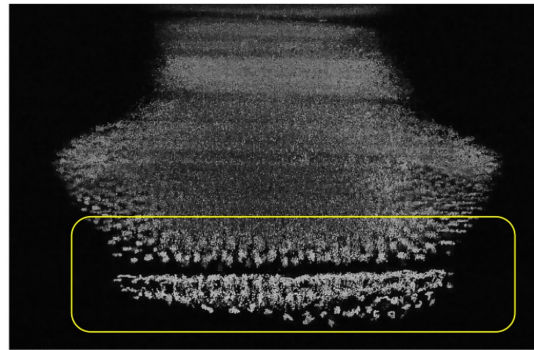
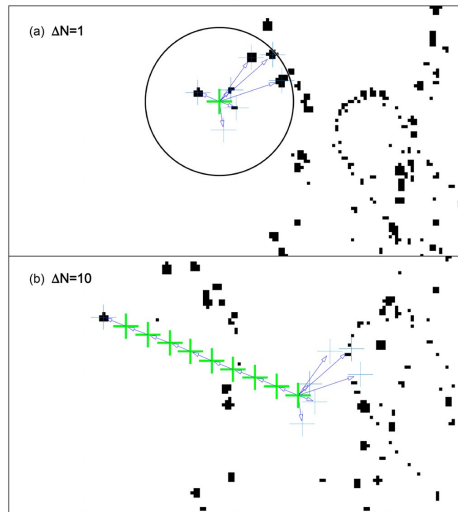


Cam A

Cam B

- Particle tracking tools for a large number of particles
- Introducing weak magnetic field to an existing exp.

# Neural networks for particle tracking



Z. Wang, et al, Phys. Plasma. **27** (2020) 033703.

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LANL Jan 2021

Z. Wang Slide 9

# Summary

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- **Dusty plasmas are promising new platforms for laboratory astrophysics**
  - Dynamo physics
  - MRI physics
  - Could be more (for example: Paul Bellan's talk from Caltech)
- **Such experiments will be empowered by ML methods that became available just recently**
- **Laboratory experiments pave the way towards ISS experiments/COMPACT in the near future**
  - Introducing weak magnetic field to an existing experiment as a first step.